Coherent Detector for Near-Angle Scattering and Polarization Characterization of Telescope Mirror Coatings

Principal Investigator: Steven A. Macenka, Optics Section 383
Co-I's: Russell A. Chipman, Brian Daugherty, Stephen McClain,
College of Optical Sciences, University of Arizona

Project Objective:

The Terrestrial Planet Finder Mission seeks to detect extrasolar planets at a contrast of 10^{12}. This requires very tight tolerances on all optical system specifications. Wavefront control and mirrors substrate surface quality have been addressed as demonstrated on JPL's high contrast imaging facility. The effects of near angle scatter and the slight depolarizing properties of metal coatings on image formation at these levels are not well understood. We have developed and built the small angle polarimetric scatterometer to characterize metallic coated mirror samples. Our project objectives were:

- Design and build an coherent imager capable of performing high contrast measurements at small scattered light angles.
  - Measure scattered light at 20 arcsec and further from point spread function (PSF) center
  - Measure PSF with a contrast of 10^6
- Study mirror samples.
- Characterize imager's impulse response.
- Develop a plan to scale the system to the angles and contrast that are necessary to verify the near angle scatter of mirrors for systems like the TPF.

Benefits to NASA and JPL (or significance of results):

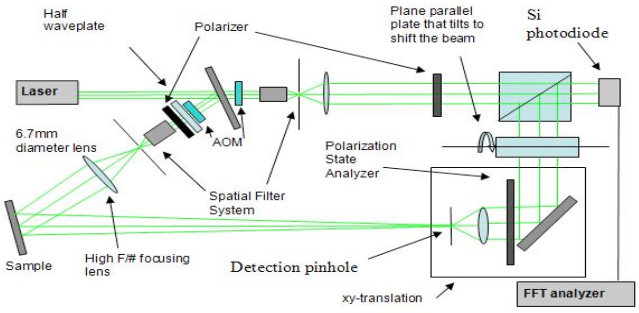
This project has demonstrated the potential of coherent detection to address the scattering metrology needs for mirror coatings for TPF missions. This coherent imager is scalable for measuring large mirrors within an arc second of the specular peak. The metrology can be applied to test and develop coating techniques for extremely low-scatter applications. It enables the study and minimization of the effects of columnar microstructures that have been found in metallic coatings.

FY09 Results:

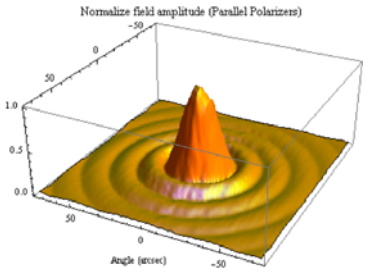
We have developed a coherent detection imager to measure the polarization dependent scattering properties of metallic mirror coatings at very small scattered light angles with these goals:

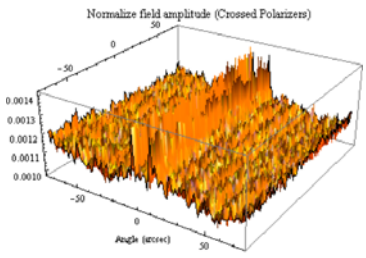
- Achieve high dynamic range
- Measure low scattered light levels
- Characterize polarization sensitivity
- Minimize unwanted scattered light within test

Heterodyne detection is used to measure the point spread function (PSF) produced by reflecting a diffraction limited high f/# beam from a sample mirror. The resulting PSF is compared to the ideal system PSF to characterize the near angle scattering of the mirror. We exploit the high contrast in the nulls of the PSF to optimize scattered light SNR. The first null occurs at 20 arc sec. We achieve a contrast of $>10^6$ at the null occurring at ~100 arc sec.



Coherent detection measures the electric field amplitude not the irradiance. We can scan the entire PSF in a single scan due to our large dynamic range. The plot below and left shows the impulse response measured for a high quality mirror sample between parallel polarizers. The scattered light data component is calculated by deconvolved the ideal PSF from the measured data. A measurement of the sample between crossed polarizers, shown in the plot on the right, shows evidence of small anisotropic polarization effects expected from reflection from anisotropic columnar microstructure found in metallic mirror coatings. Further measurements should be taken to confirm and further quantify these effects.





Publications:

A paper describing the instrument and initial testing results on mirror samples is in preparation.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Poster No. 09-163